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IPAD—Integrated Programs for Aerospace-Vehicle Design

Ralph E. Miller, Jr.

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IPAD—Integrated Programs for Aerospace-Vehicle Design

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Prepared for
Langley Research Center
under Contract NAS1-14700

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National Aeronautics
and Space Administration

Scientific and Technical Information Branch

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IPAD

Integrated Programs for Aerospace-Vehicle Design
Contractor's Final Report
June 1, 1984

Prepared Under Contract NAS1-14700 by
Boeing Commercial Airplane Company
for
Langley Research Center
National Aeronautics and Space Administration

Abstract

Early work is being done to apply data base technology to support the management of engineering data in the design and manufacturing environments. The principal objective of the IPAD project was to develop a computer software system for use in the design of aerospace vehicles. Two prototype systems were created for this purpose. Relational Information Manager (RIM) has become a successful commercial product. IPAD Information Processor (IPIP), a much more sophisticated system, is still under development.

Acknowledgment

IPAD has been a real team accomplishment. Starting from their broad range of specialties, people stretched their minds and escaped from their usual narrow compartments. They examined the total concept of air vehicle design and its computer environment implications.

Many of us saw, for the first time, our roles within the engineering data management process. It was a refreshing, challenging view. The product that has emerged was shaped first by the requirements of people and their tasks in the design process, then modified by a computer system design and prototype software that set the stage for a new level of human/computer productivity.

The vision of NASA in sponsoring this step, and the judicious guidance of the Industry Technical Advisory Board (ITAB), has helped propel United States industry into a potentially more productive, cost-effective environment.

Ralph E. Miller, Jr.
IPAD Program Manager

IPAD Program Summary

Contract Background, Goals and Objectives

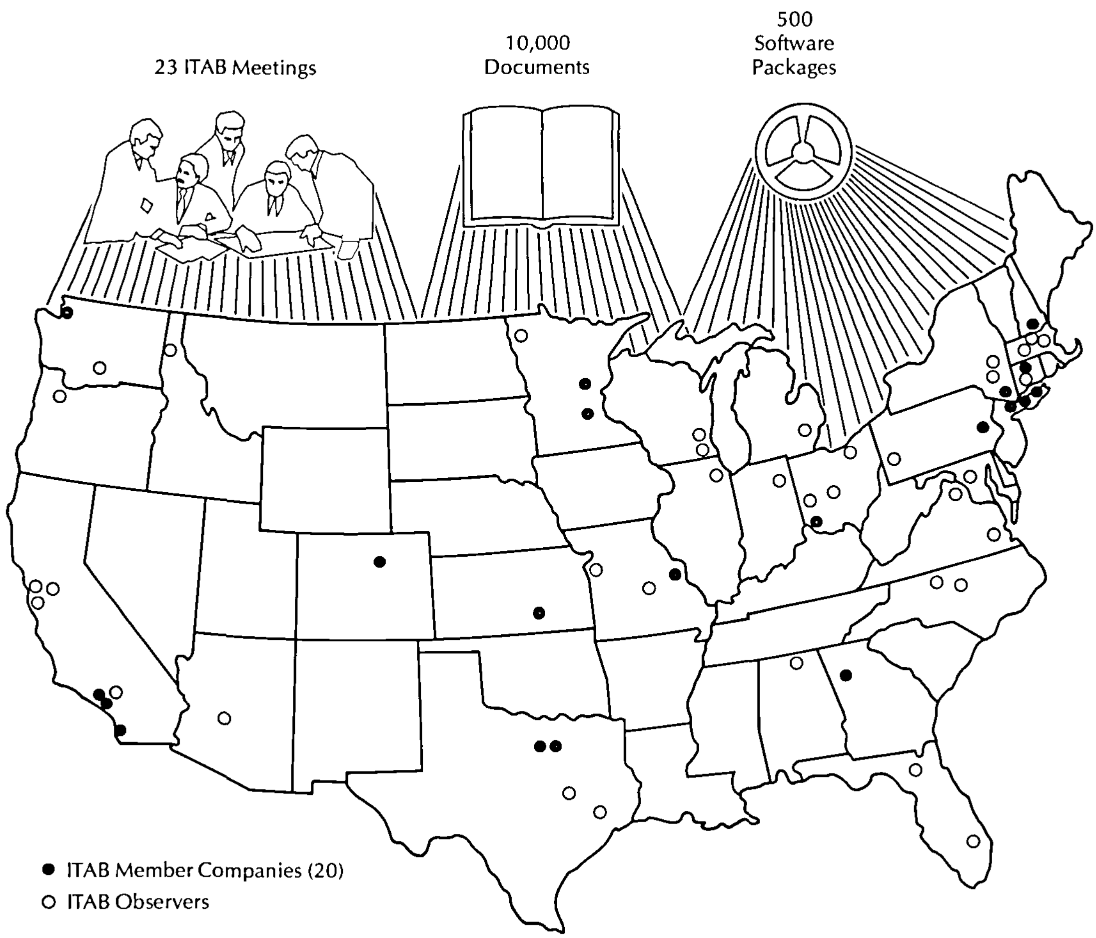
In 1976, NASA selected Boeing Commercial Airplane Company to develop Integrated Programs for Aerospace-Vehicle Design (IPAD). The principal objective of the project was to develop a prototype computer software system that would reduce time and cost in the design of aerospace vehicles and promote improved vehicle performance.

Technology Transfer

The Industry Technical Advisory Board (ITAB) was created to advise Boeing Program Management during the research work and, in return, receive the research results. Twenty-three ITAB meetings have been held to the mutual benefit of both the program and industry. ITAB has been an effective medium for disseminating IPAD research results. Over 10,000 copies of documents and reports and more than 500 software packages have been distributed to U.S. industry.

Significant Findings

Initial studies indicated that the system would need to support a distributed, heterogeneous machine environment in which data base management technology and networks played critical roles. The IPAD project designed two prototype systems based on these requirements.

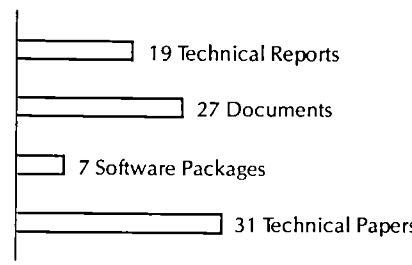


Relational Information Manager (RIM) was developed in 1979 as a demonstrational prototype of an engineering data base management system (DBMS) capable of operating in a heterogeneous machine environment. By 1983, RIM had become a successful commercial product marketed by several vendors.

IPAD Information Processor (IPIP) is a much more sophisticated prototype than RIM. It is a multimodel, multiuser, multilevels of schema, concurrent access DBMS that includes the data definition language (DDL) and data manipulation language (DML) required for geometry and engineering problem solving.

Research Results

The IPAD project prepared and released 19 technical reports, 27 documents, 7 software packages, and published 31 papers in the open technical literature.



IPAD Program Contract Background

Feasibility Study

Prior to contract NAS1-14700, Boeing Commercial Airplane Company was selected in 1972 by NASA in a competitive procurement to perform a feasibility study for an Integrated Program for Aerospace-Vehicle Design (IPAD). The intent was to analyze and describe the product design process and to seek ways to improve the productivity of people and computers in support of this process.

The feasibility study ended in September 1973 and produced the following reports:

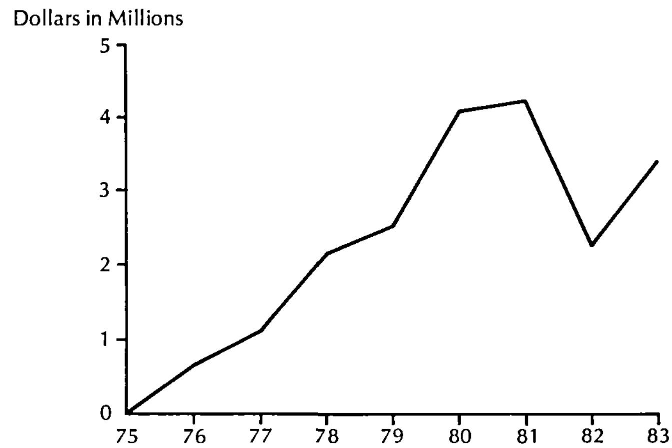
- Volume IA, Summary of IPAD Feasibility Study;
- Volume IB, Concise Review of the IPAD Feasibility Study;
- Volume II, The Design Process;
- Volume III, Support of the Design Requirements;
- Volume IV, IPAD System Design;
- Volume V, Catalog of IPAD Technical Program Elements;
- Volume VI, IPAD System Development and Operation; and
- Volume VII, IPAD Benefits and Impact.

The feasibility study was the point of departure for the development contract.

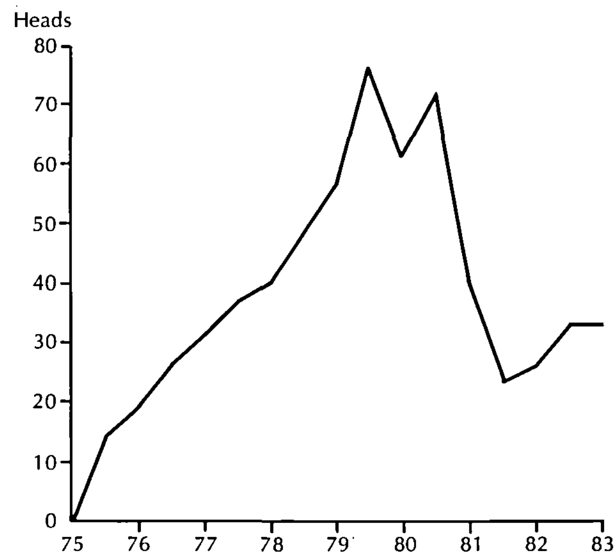
Development Contract

In April 1976, Boeing Commercial Airplane Company was selected again by NASA in a competitive procurement for the development of Integrated Programs for Aerospace-Vehicle Design (contract NAS1-14700). The principal objective of the IPAD project was to develop a computer software system for use by the U.S. aerospace industry in the design of future vehicles. This system was intended to substantially reduce time and cost and to foster improved vehicle performance.

The contract development staff and funding are shown below.



IPAD Program Annual Expenditure (Cost Plus Fee)



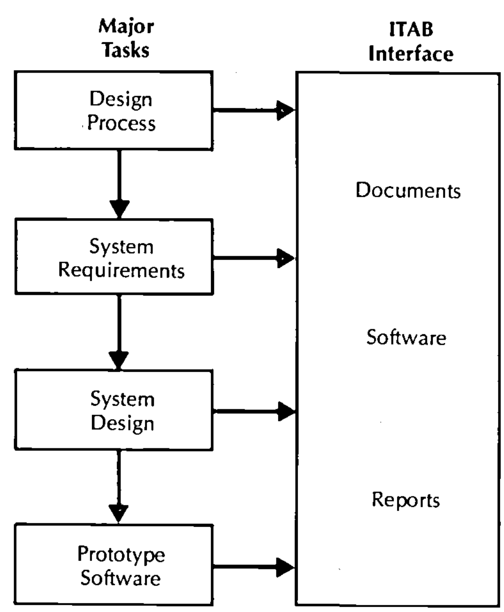
IPAD Program Annual Headcount

Goals and Objectives

The work began with the preparation of specifications and preliminary design for an IPAD system. Scheduled to be operational in the 1980s, the system was to support the full engineering activities of a large aerospace organization composed of many people working on many projects at several levels of design over long periods of time. The second goal was the design, coding, documentation, testing, and release of a prototype version of a total IPAD system.

To achieve these goals, the work was broken into four major tasks. IPAD requirements were defined by an examination of the aerospace design process and its interactions and interfaces with manufacturing. Aerospace design integrated information processing requirements were established. A software specification and preliminary design of a full IPAD system were prepared to support the requirements for aerospace design. Finally, a partial version of the full IPAD system was developed, resulting in prototype software that addressed the needs of U.S. industry.

In addition to the technical objectives, it was important to disseminate the development results. This led to the establishment of the Industry Technical Advisory Board (ITAB) as an interface with U.S. industry. ITAB's function was to review, critique, and provide feedback to the contractor and thereby guide the development in the best interest of U.S. industry. ITAB was also the major recipient of the research results.



IPAD Program Significant Findings

Engineering Requirements

During the initial phase of the program, studies were made that subsequently guided the development of the IPAD system. Documents resulting from those studies include

- Reference Design Process, D6-IPAD-70010-D,
- Product Manufacture Interactions with the Design Process, D6-IPAD-70011-D,
- Product Program Management Systems, D6-IPAD-70035-D,
- Integrated Information Processing Requirements, D6-IPAD-70012-D, and
- IPAD Requirements, D6-IPAD-70040-D.

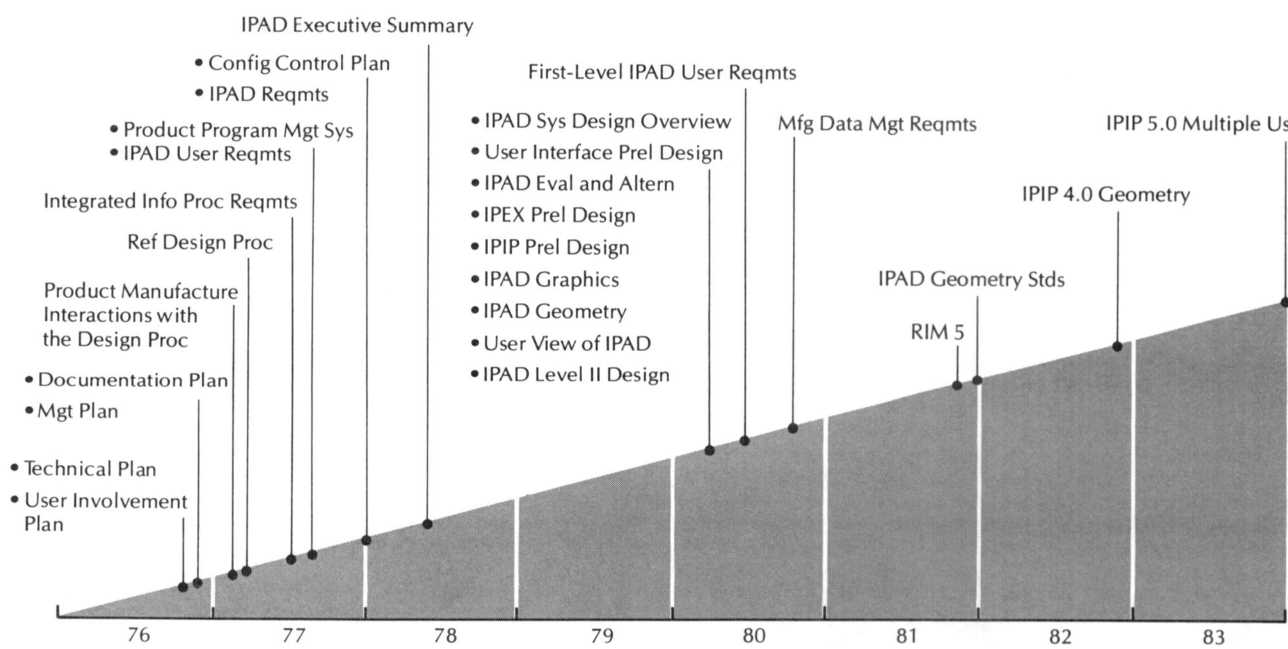
These documents, which provided a description of the future system needed by industry, were evaluated and approved by an ITAB subcommittee.

The requirements were for a general purpose, interactive computer aided engineering system capable of supporting engineering data associated with the design process, including manufacturing interfaces. The system would serve management and engineering staffs at all design levels as well as the downstream manufacturing processes. Although it would be capable of operating in a single host environment, normally the system would employ a distributed environment using multiple hosts of diverse types and manufacturers. These computers would be located in varying degrees of geographic separation and would be connected by a high speed communications network. The system would support the generation, storage, and management of very large quantities of data.

Definition of a Future System

The IPAD staff produced a preliminary design based on the engineering requirements for a future system. This design focused on a distributed, heterogeneous machine environment in which data base management technology and networks played critical roles in the total solution.

Other areas of the preliminary design included work in geometry, graphics, and user-friendly executives. In 1978, NASA and ITAB decided to concentrate IPAD resources on two areas: (1) data management, and (2) networking between heterogeneous machines.

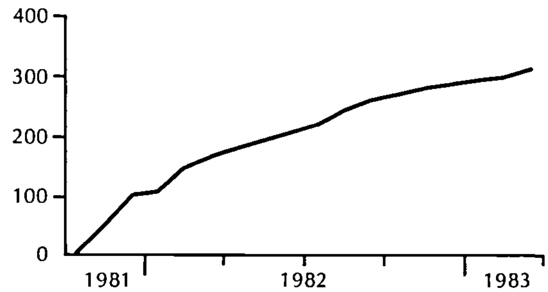


Prototype Systems

The progression from autonomous engineering application systems to fully integrated data management is still in its infancy. The first steps are being taken in the application of data base technology to support engineering data and its uses in the design and manufacturing environments. The IPAD project designed two prototype systems — Relational Information Manager (RIM), and IPAD Information Processor (IPIP). Projects like IPAD and the use of prototype systems like RIM and IPIP provide the feedback to improve the DBMS support of engineering data types and geometry.

Relational Information Manager — RIM

One of IPAD's primary interests was an engineering data base management system (DBMS) capable of operating in a heterogeneous machine environment. As no such DBMS was commercially available in 1978, a prototype called Relational Information Manager was developed in 1979 to demonstrate the viability of the basic system concept. RIM had evolved into an independent product (RIM 5.0) by 1981 and was subsequently distributed to well over 300 companies, government organizations and universities as shown above. RIM has been enhanced by the University of Washington and Boeing Computer Services Company in cooperation with ITAB and the IPAD project.



IBM	46
CYBER NOS	37
DEC VAX	161
PRIME	35
CYBER NOS/BE	13
UNIVAC	11

IPAD RIM Distribution (April 1, 1983)

A RIM data base may be accessed in read mode by multiple users, but access for update is restricted to a single user.

RIM supports a single level of data definition. Relations are defined in schemas that are entered and modified interactively through a menu interface. Rules on data relationships within and between relations may be declared. Rules can be used as constraints, although the user may turn rule checking off and on. Security is provided through read/write passwords assigned at the relation level.

RIM provides scientific support capabilities with its matrix, vector, and real data types, as well as its character (text) and integer data types. It also has a tolerance capability for qualification by a user-specified approximation of equality.

The system offers both algebra-level (including join) and calculus-level (excluding join) data manipulation commands through an interactive interface, along with facilities that format retrieved data. It supports the calculus-level data manipulation commands for FORTRAN programs by means of subroutine calls.

Written primarily in FORTRAN 66, RIM will also compile in FORTRAN 77. It may be installed on several hosts, including CDC, IBM, UNIVAC, DEC, and PRIME computer systems.

By 1983, RIM had successfully migrated to the commercial environment. It had become a product marketed by at least three companies and was an integral part of other commercially available products. At NASA's request, the IPAD program ceased to distribute RIM in September 1983. However, it has been a very successful IPAD spin-off product and is a de facto standard throughout industry and government.

IPAD Program Significant Findings

Prototype Systems

■ IPAD Information Processor — IPIP

IPAD Information Processor, a much more sophisticated prototype, was also evolving in the period from 1980 to 1983, along with specialized network technology. Improvements can be made in the way information is managed and shared. IPAD has demonstrated this by implementing the multimodel (including geometry), multiuser, multilevel schema, concurrent access DBMS (IPIP, IPIP utilities, and IPAD Network) that includes the data definition language (DDL) and data manipulation language (DML) required for engineering problem solving.

By addressing the heterogeneous machine environments, and by investigating and implementing neutral (standard) data interchange conventions, IPAD has also shown that the boundaries of the traditional engineering environment can be expanded. Thus, research could proceed to determine the path that must be taken to implement the single enterprise data base from design through manufacturing.

■ IPIP Technical Features

The engineering data base management system, IPIP, employs a multilevel schema architecture, an extension of the three schema model introduced by the ANSI/X3/SPARC Data Base Study Group (DBSG). It is a multimodel (relation, hierarchy, and network) architecture. These features promote a high degree of data independence. IPIP is a multiuser and multithread DBMS that provides users with engineering data types (e.g., floating point numbers, arrays, etc.) and the ability to store and retrieve geometry. IPIP currently operates on CDC CYBER series machines under NOS.

The IPAD network system provides the equivalent of levels 3 through 6 of the ISO seven-level model of communications. The system uses Network System Corporation's Hyperchannel to provide process-to-process communications (levels 1 and 2 of the ISO model) between a VAX 11/780 under VMS and a CDC CYBER 835 under NOS.

The integration of these technologies allows programs written in FORTRAN and hosted on either a VAX or a CYBER 700 series machine to store or request data from the data base and to use the data in its native machine code. IPAD software consists of approximately 200,000 lines of Pascal code.

■ Multiple Data Models — IPIP

The IPIP data base management system is intended to manage engineering data throughout the product life cycle in CAD and CAM environments. Therefore, IPIP supports multiple data models, multiple levels of schemas, and concurrent multiple user access through multiple application interfaces in a distributed environment.

The system supports scientific data types and arrays. Complex objects called structures, which may consist of multiple tuples from multiple relations, can be declared and manipulated as entities to manage geometry and other scientific data. Data may be partitioned logically into data sets to allow concurrent access. Data sets provide the hook for follow-on capabilities such as versioning, releasing, and archiving procedures.

■ Standards — IPIP

One major objective of IPIP has been compatibility with specifications for data definition and manipulation languages that seem to be leading to a standard. This approach takes advantage of previous work and tested constructs, facilitates migration between standard compliant systems and IPIP, and simplifies incorporation of IPIP extensions into standards. Language development drew on the work of the CODASYL and ANSI committees, and recognized the engineering requirement for a FORTRAN interface. The IPIP Logical Schema Language (LSL) was based on a subset of the 1978 CODASYL Data Description Language (DDL). The IPIP Data Manipulation Language (DML) was based on a subset of the 1978 CODASYL FORTRAN DML. Extensions and improvements from these specifications were made in some instances.

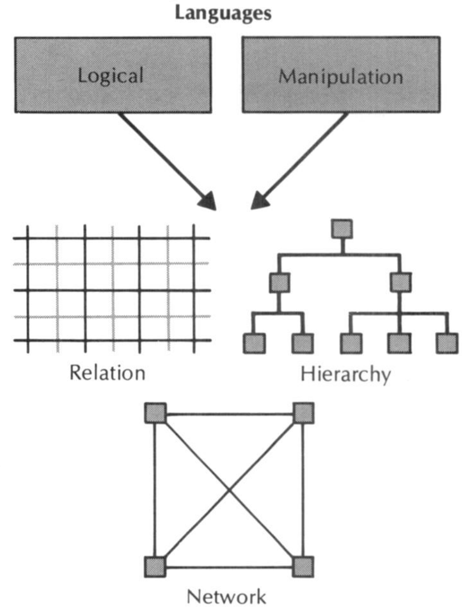
IPAD Program Significant Findings

Prototype Systems

■ Languages — IPIP

Integration of capabilities and user interfaces has been another major objective of IPIP. A single LSL and DML supports the relational, hierarchical, and network data models and applications, either interactive or written in one of several programming languages. The LSL is used at both the conceptual and external levels of data definition. The Internal Schema Language (ISL) resembles the LSL as nearly as possible. Scientific features such as the structure-defined complex objects for geometry are integrated with other data management capabilities.

Multiple Data Models Languages



■ Multilevel Schemas — IPIP

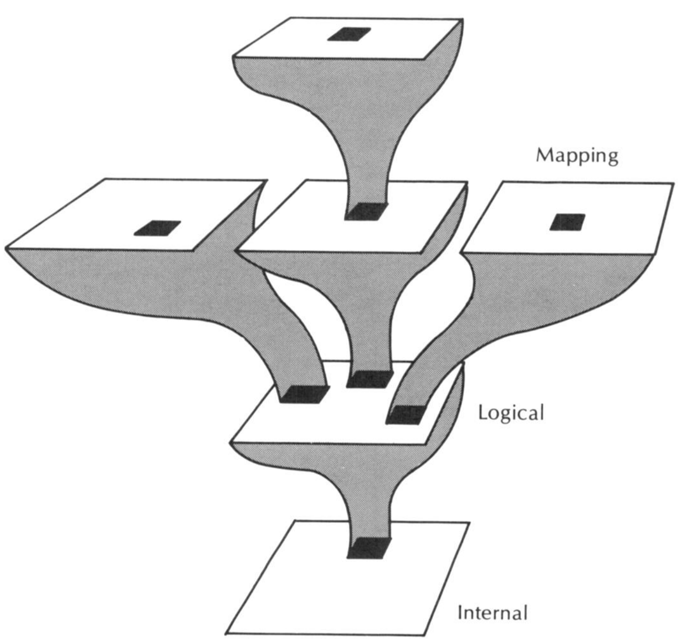
There are three types of IPIP schemas — internal, logical, and mapping. The IPIP internal schema corresponds to the internal schema of the ANSI DBSG and the storage schema of the CODASYL Data Description Language Committee. IPIP logical schemas correspond to ANSI conceptual and external schemas and also to CODASYL schemas and subschemas. The mapping schema is used for mapping between logical schemas and between schemas of the other two types.

An IPIP data base is described by a single level of internal schemas and one or more levels of logical schemas mapped to underlying logical and/or internal schemas. An application program or session may be formulated against logical schemas at any level.

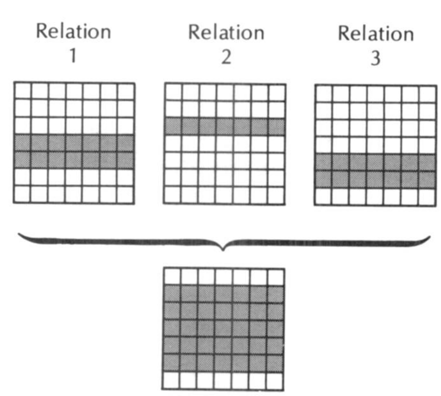
Currently, attributes of IPIP relations may be integer, real, character, or Boolean scalars or arrays. Selection and projection on individual elements of an array is not supported at this time.

■ Data Sets — IPIP

IPIP supports initial capabilities for data set partitions. A data set is declared implicitly on first user access. Data set intersections with relations are the units of locking data for read and update. Access by data set is supported by IPIP indexing (B-tree). IPIP indexing and address conversion structures were designed for access to versions of data sets while minimizing physical redundancy of data across versions. Data sets may be used to specify data to be processed by a prototype facility for transferring data between IPIP and RIM data bases.



Multilevel Schemas



Data Set

IPAD Program Significant Findings

Prototype Systems

■ Geometry Data Management — IPIP

Structures manage geometry and other scientific data. A structure in a logical schema consists of tuples from a tree or network of relations as related by foreign keys. It may also be defined in terms of records and sets. A relation/record in one logical schema may be mapped to a structure in another schema. Such a relation/record is said to be structure-defined. A structure is manipulated (retrieved and updated) as an entity through operations on a structure-defined relation. The same commands are used for nonstructure-defined records.

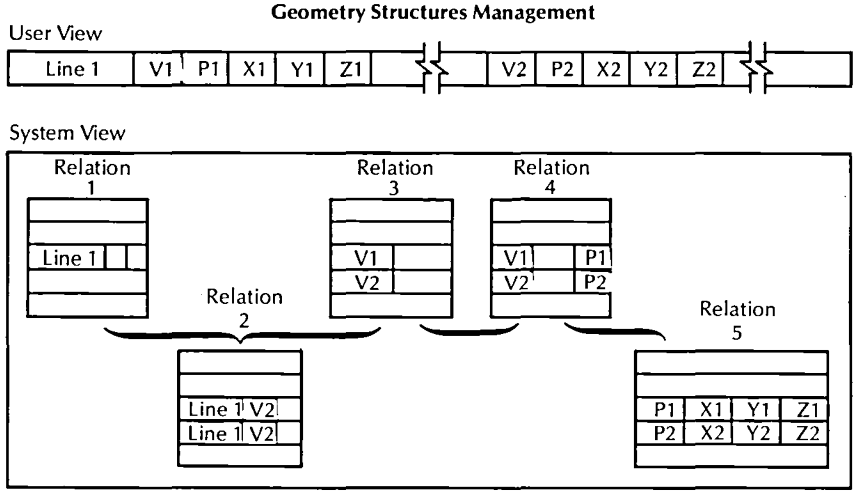
A user accesses structure-defined data at the entity (e.g., surface, curve, segment) level. One command may result in processing multiple underlying tuples as specified by schema-declared constraints and propagated actions for relations and foreign keys within the structure. When storing data, IPIP will generate values for unique keys the user has left undefined. IPIP will sequence retrieved data according to schema specification for inclusion in the structure-defined record. Productivity is enhanced through support of entities which are natural to the user's application. Data integrity is ensured through definition of structure processing in the schema. This avoids the necessity for complicated command sequences embedded in numerous applications. Data integrity also benefits from IPIP's awareness and enforcement of the semantics (e.g., constraints) of the geometric data as described in the schema. In this situation, IPIP is managing geometry, not just data without an intrinsic meaning.

■ Provisions for Distribution — IPIP

Some initial capabilities for distributed processing are in place including the IPAD network and the VAX interface to CYBER data bases. The ability to loosely couple IPIP data bases has extensive potential for distributed data management.

IPAD developed a general purpose network facility for intertask communication in a heterogeneous distributed processing environment. The IPAD network was implemented in accordance with ISO specifications of layered protocol. Access to IPIP and IPIP-managed data is by means of this network. IPIP and the network are written primarily in Pascal.

Geometry Structures Management



Compilers and Precompilers — IPIP

IPIP provides compilers for schemas and precompilers for processing data manipulation commands within CYBER and VAX FORTRAN programs. These compilers, precompilers, and user applications access IPIP data management services through the IPAD network. IPIP and its compilers and precompilers execute on CYBER equipment. Program precompilation and execution may be launched from either CYBER or VAX. Actual compilation, precompilation, and execution of data manipulation commands are executed on the CYBER. Results are returned through the network.

Examples of Engineering Data Schemas — IPIP

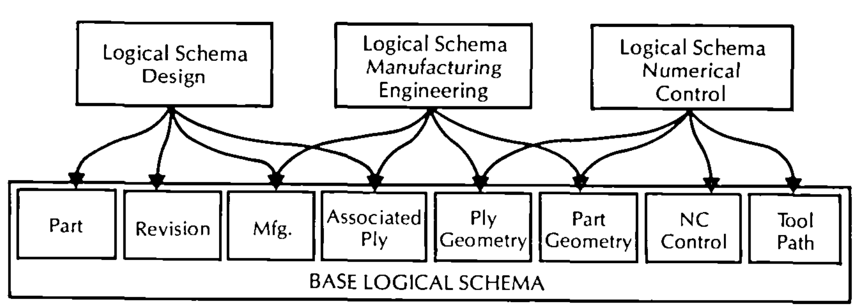
A variety of schemas relating to engineering data were written on the IPAD project, most of them using the relational data model. Schemas used for geometric data were documented in IPAD Technical Report WBS 4.2, Design and Implementation of Geometry Processing in IPIP. The geometry schemas, along with an example program using them, were included in IPAD Release 5.0.

The IPAD project has written schemas dealing with a number of phases of the engineering and manufacturing processes. Schemas containing information about the initial configuration of an airplane reflect some of the data needs for the first step in a design process. This set is being used in an interactive program currently undergoing testing. This program allows the user to create wire frame models of wings, horizontal stabilizers, vertical fins, and constant body sections.

Another set of schemas deals with data used by an existing finite element analysis program. Sample programs for these schemas were written to pre- and postprocess that data in the data base before and after executing the finite analysis program. Schemas reflecting some of the data needs of manufacturing were originally intended for use with IPIP, but were implemented in RIM for the Manufacturing Pilot (see Manufacturing Pilot User Guide, UM-REL5-400).

Work continues on a set of schemas to support the data needs of the Advanced Composites Development Group at Boeing. These schemas encompass some of the data needs of design, manufacturing, and numerically controlled (NC) programming. They will utilize a multiple user view capability through a logical schema for each discipline and will contain pointers to the IPAD geometry schemas.

Work was also done in conjunction with General Dynamics to develop schemas for storing some of the data output by an existing vehicle design evaluation program, VDEP.



Research Results

The IPAD project conducted its research and development with a staff of engineers and software analysts organized into a development team. The team was well-supplied with computing terminals and support devices and had the services of a dedicated computer laboratory. Research results were reported to NASA and U.S. industry as technical reports, documents, prototype software packages, and technical publications in open literature.

IPAD Computer Laboratory

The IPAD computer laboratory shown below currently is comprised of an IBM 4341 Model 2, a CDC CYBER 835, and a DEC VAX 11/780, all interconnected by a high-speed Hyperchannel bus manufactured by Network Systems Corporation. This dedicated facility provides local services of approximately one terminal for each member of the development staff. Communication to the development staff in an adjoining building is by a multiplexer system enabling access to all the IPAD computer systems. The development area contains 35 terminals as well as local printing.

Technical Reports

Appendix A lists the 19 technical reports prepared and released to NASA and U.S. industry during the progress of the work. These reports explored design issues concerned with interfaces to IPAD tasks and with network communications protocols, and examined distributed computing and provided functional and design alternatives for distributed data base management systems. Application of the data management systems to storage and manipulation of geometry data was studied, as well as the application of the data management systems to integrate engineering application programs. Two reports presented results of performance modeling analysis of the IPAD prototype on CDC and DEC computers.

Technical Documents

Appendix B lists 27 documents prepared and released to NASA and U.S. industry. The Technical Plan and Management Plan established the technical objectives and approach and a management structure with delegation of responsibility and authority to carry out the work. The User Involvement Plan provided the organization and operation of the Industry Technical Advisory Board as a mechanism for review and recommendation on the contractor's development results. Standards and methods of maintaining configuration control of the technical results were documented. Case studies provided an integrated view of the engineering design process, its interaction with product manufacturing, and the program management process during the creation of a product design. Other documents detailed the information processing and user function requirements for a computer-based system to be used in support of engineering. A preliminary design of a total IPAD System covered a system overview, user interface, executive, data manager, graphics, geometry, user's view, design decomposition to level 2, and evaluations and alternatives.

Research Results

Prototype Software Packages

Appendix C lists the seven software packages and accompanying documentation that were produced and released to NASA and U.S. industry throughout the technical development.

Manuscripts in Technical Literature

Appendix D lists the 31 papers published by the IPAD staff in the open technical literature between 1976 and 1983. These papers included discussions of general IPAD concepts and significance to industry, geometry and geometry data base management, engineering data base management, IPAD system and system component function and design, and engineering requirements for IPAD systems.

Distribution of Results

Regular communication was maintained with NASA and ITAB through the Monthly Technical Progress Narrative Report. This report provided a brief synopsis of the work in progress.

In addition, the IPAD project distributed the research results to U.S. industry upon request. In this contract period more than 10,000 copies of documents and 500 copies of software packages were distributed. The distribution of these results to major organizations in the United States is shown below.

IPAD Product Distribution

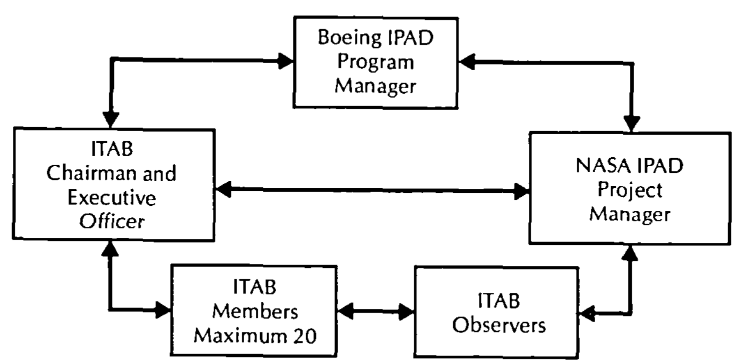
Product	Number of Copies	Number of Organizations	
Documents	11,182		
Software Packages	569	• Universities	67
		• Industry	236
		• Government	13

Industry Technical Advisory Board (ITAB)

A major objective of the IPAD project was to transfer technology to U.S. industry. The organization and operation of ITAB were highly instrumental in achieving this objective.

ITAB was composed of representatives from U.S. industry. Twenty of these representatives were members of the advisory board and over 80 additional representatives were observers. The ITAB chairman was from industry and was supported by an ITAB executive officer from the IPAD staff. The relationships between ITAB, the contractor, and NASA are shown below. This arrangement ensured direct communication between ITAB and the contractor while at the same time maintaining strong communication with NASA. The members and observers of ITAB are shown in appendix E.

Meetings were conducted with ITAB at approximately three-month intervals. Between 1976 and 1983, 23 meetings were held at various member company sites. Typically these meetings included NASA, Navy, and IPAD program status reports, ITAB subcommittee reports on reviews of the contractor's work, and recommendations to the contractor.



IPAD Organization and Communication Channel

Technology Transfer

Impact on Hardware and Software Vendors

The IPAD project affected vendors in several ways.

(1) New companies were formed whose initial products were based on IPAD prototype software.

(2) Vendors introduced new products based on IPAD prototype software.

(3) IPAD prototype software was embedded within integrated hardware and software products or within new application software packages.

Two new companies — MicroRIM, Inc., Bellevue, Washington, and RIM Technology, Inc., Redmond, Washington — offer RIM-based products and services.

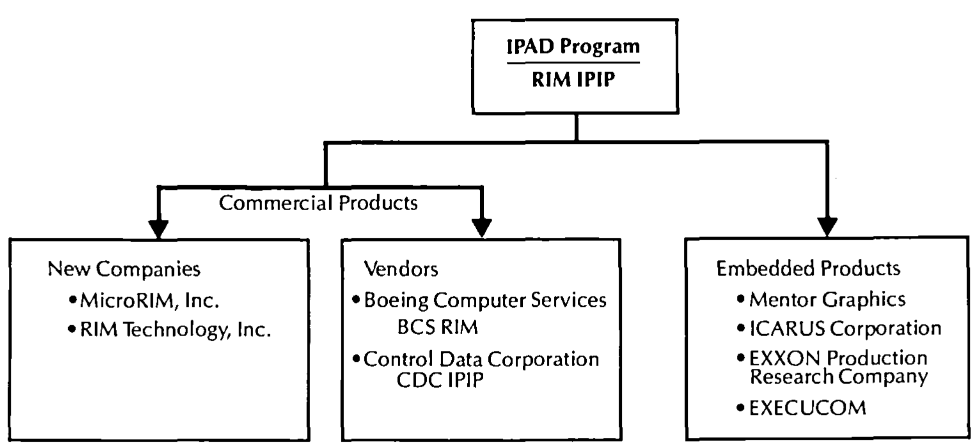
Boeing Computer Services Company expanded its product line on July 28, 1982 to offer BCS RIM, an enhanced version of IPAD RIM.

In April, 1984, Control Data Corporation will offer a product called CDC IPIP.

At least four companies have embedded IPAD RIM software in their product lines and are commercially marketing the resulting products both within the United States and to foreign customers. Among these are:

- Mentor Graphics, Beaverton, Oregon; electronic design applications.
- ICARUS Corporation, Rockville, Maryland; construction estimating and scheduling applications.
- EXXON Production Research Company, Houston, Texas; geological support applications.
- EXECUCOM, Austin, Texas; interactive financial planning systems.

In addition, NASA Langley has adopted RIM as the basis of integrated application development.



Conclusions

Four general conclusions can be drawn from the seven years of the IPAD program.

The IPAD studies of engineering processes and the interactions with a broad segment of U.S. industry, through the mechanism of ITAB, molded an industry consensus of requirements for future computer-based engineering systems.

The extensive IPAD development work provided useful prototype software for advanced network communication and engineering data management, illustrating the nature of future products.

IPAD tutorials, reports, and applications established the advanced technology of engineering data management, data schema with specific examples from areas of geometrical parts, composite material structure, and integration of engineering applications with an engineering data management system.

The aggressive development of a software prototype stimulated vendors to produce new products in the areas of data management and network communication.

Appendix A: IPAD Technical Reports

Originating WBS No.	Report No.	Reporting Title and Description
3.2.1	1	"Definition of IPSR Processes." A list and associated description of services needed by IPAD tasks.
3.2.2, 3.2.3	2	"IPSR Interface Definition." Definitions of IPAD task to IPSR interfaces; for IPR functions.
3.4.1, 3.4.3	3	"Definition and Specification of Interfaces for Data Collection." Method of collection for system performance.
3.5.1	4	"Report on Study of Existing Network Communication Protocols." Recommendations for use of an existing protocol or designing one for IPAD.
3.5.1	5	"Recommended IPAD Network Communication Protocols." A preliminary protocol specification.
3.5.1	6	"Final Specification of IPAD Network Communication Protocols." A preliminary protocol specification.
3.5.2	7	"Message Interface Definition." Message transfer interface and applicability to IPAD functions.
3.5.2	8	"Connection Interface Definition." Connection interfaces by IPAD tasks and method implemented.
3.10-1	9	"An Overview of Distributed Computing in the Engineering and Manufacturing Environment." Four basic topics: objectives of distributed processing, components of distributed processing, work stations, and possible distributed processing architectures.
3.10-2	10	"Functional and Design Alternatives for Distributed Data Base Management Systems in the Engineering and Manufacturing Environment." Alternatives that should be considered in designing a distributed data base management facility.
4.2	11	"Design and Implementation of Geometry Processing in IPIP." Application of IPAD DBMS concepts to the storage and manipulation of geometric data. The features of IPIP designed to support the management of geometric data are discussed. The functional capabilities for manipulation of geometric data are described in terms of IPIP DML commands and the schemas developed for geometry.
4.2.2	12	"Literature Search and System Survey Distributed Computing." Research and recommendations on distributed data processing.
5.2.1	13	"Interim Report on Integration of Program and Data." Results of studying the use of a data management system with engineering application programs including sample engineering scenarios.
5.2.4	14	"Protocol Specifications for Integration Programs Into IPAD." Documentation of procedures, sample programs, and scenarios showing full integration of user-written programs using IPIP.
5.4.4	15	"Interim Report — Geometry Data Management." Description of the procedures and data structures used in the RIM prototype geometry task.
5.4.5	16	"Geometry Multiple Representation." Discussion of the canonical forms used in the RIM prototype work and associated ANSI transformations for these entities.
6.1.1	17	"Report on NOS Model (EX IPIP)." Results of performance modeling analysis of IPAD prototype on the CDC CYBER 172 using NOS and recommendations for change to the IPAD prototype, NOS, or the host computer.
6.1.1	18	"Report on IAS Model (EX IPIP)." Results of performance modeling analysis of the IPAD prototype on the DEC PDP 11/70 using IAS and recommendations for changes to the IPAD prototype, IAS, or the host computer.
6.1.1	19	"Report on System Design Evaluation." The final report on the evaluation of the IPAD prototype. It will contain quantitative results of throughput, performance, and component utilization analysis. It will identify discrepancies between the system and the requirements for first-level IPAD. It will provide quantitative descriptions of the host capabilities required and make recommendations for changes to host hardware and software.

Appendix B: IPAD Documents

Document No.	Document Title
D6-IPAD-70000-P	Documentation Plan
D6-IPAD-70001-P	Management Plan
D6-IPAD-70002-P	Technical Plan
D6-IPAD-70003-P	User Involvement Plan
D6-IPAD-70005-P	Configuration Control Plan
D6-IPAD-70010-P	Reference Design Process
D6-IPAD-70011-D	Product Manufacture Interactions With the Design Process
D6-IPAD-70012-D	Integrated Information Processing Requirements
D6-IPAD-70013-D	IPAD User Requirements
D6-IPAD-70015-D	IPAD Geometry Standards
D6-IPAD-70016-D -1,2,3	First-Level IPAD User Requirements, Vols. 1,2,3
D6-IPAD-70020-M	IPAD Executive Summary
D6-IPAD-70035-D	Product Program Management Systems
D6-IPAD-70036-D	Vol. 1 IPAD System Design Overview
	Vol. 2 User Interface Preliminary Design
	Vol. 3 IPAD Evaluations and Alternatives
	Vol. 4 IPEX Preliminary Design
	Vol. 5 IPIP Preliminary Design
	Vol. 6 IPAD Graphics
	Vol. 7 IPAD Geometry
	Vol. 8 User View of IPAD
	Vol. 9 IPAD Level II Design
D6-IPAD-70038-D	Manufacturing Data Management Requirements
D6-IPAD-70040-D	IPAD Requirements
D6-IPAD-70046-R	Guidelines for Management of Manufacturing Information

Appendix C: IPAD Prototype Software Releases

Release 0.0:
IPAD Integration Prototype System

Prototype GRTS (RG library)
Patch II display (RD library)
Patch II user interface (RU library)
IPAD integration prototype:
- AD-2000 postprocessor to RIM
- Finite-element modeler
- Preprocessor to ATLAS and SPAR
- Postprocessor to ATLAS

RIM II
GPGS
AD-2000 (PDP 11/70 — IAS, VAX/VMS)
Pascal compiler
CDC/DEC communications package
SPAR
ATLAS

Release 1.0:
Overview

Release 1.0 provides the fundamental data management capabilities and the internal communications facility for the CYBER. It can be used to demonstrate fundamental data processing capabilities of IPIP and make an assessment of the effort required to install the system software. Release 1.0 may only be used with the application that is delivered with it.

This release contains the following functional subcomponents:

- IPIP data manager, record processing
- IPEX service for data transformation between CYBER and the network standard
- IPEX CYBER host service access as required
- IPEX CYBER intrahost communications
- CYBER Pascal compiler
- GPGS
- IPIP demonstration program
- Installation instruction

Release 2.0

This release contains all of release 1.0 and the following functional components:

- Data definition language compilers
- CYBER data manipulation precompiler
- Application module 7
- AD-2000, version 0.0
- ATLAS
- SPAR
- Installation instructions

Release 2.5

This release is the same as version 2.0 but with improved performance.

- Improved performance
- Record processing DML extended
- Preruntime binding
- Complete demo script — no restrictions
- Total SPRs installed since version 2.0: 159
- Updated user instructions
- Updated instruction manual

Release 3.0

This release contains all of version 2.0 plus communications and geometry to support IPIP.

- Network product
- IPIP record processing
- Multilevel schema
- Program bind
- Schema bind

Release 4.0

Version 4.0 IPAD product supersedes and replaces previous versions, supports geometry (points, lines, arcs, and objects). Performance is improved over past versions with less core required for IPIP and faster processing.

- IPIP
- IPIP compilers
- GPGS
- Installation, test, and usage instructions

Release 5.0:
Software

Version 5.0 software was released in two versions: IPIP multiuser, multithread version and a single user version (DM/SU). Both versions offered improved performance over previous versions and included geometry, Interactive Query Facility (IQF) and IGES translators. Network software and test programs were also released.

Data base manager:
- IPIP
- DM/SU

Network product
Interactive Query Facility (IQF)
IGES translators:
- GPGS
- Pascal

Application programs (test cases)
Comprehensive CCL procedures for system control

Appendix D: Manuscripts in Technical Literature

1. Miller, Ralph E., Jr.; Dube, R. Peter; Syder, Howard; and Taylor, Donald E: "Human Problem Solving Aided by Computers — What We need; What We Have; What We are Likely to Get." Invited presentation to International CAD Congress, Munich, Germany, October 1983.
2. Dube, R. Peter; and Smith, Marcia Rivers: "Managing Geometric Information With A Data Base Management System." Published in special issue of IEEE Computer Graphics and Applications, October 1983.
3. Hamed, Laura B.; and Pfeiffer, Heather, D.: "Engineering/Manufacturing Data Base Management — The IPAD Approach." Paper presented at VIM-39 Conference (CDC User's Group), October 1983.
4. Dube, R. Peter; and Johnson, H. Randall: "Computer-Assisted Engineering Data Base." Paper presented at Annual Meeting of ASME, September 1983.
5. Johnson, H. R.; Schweitzer, J. E.; and Warkentine, E. R.: "A DBMS Facility for Handling Structured Engineering Entities." Presented at SIGMOD '83 Annual Conference ACM, June 1983, published in SIGMOD Data Week Conference Proceedings — Engineering Applications, June 1983.
6. Balza, R. M.; Bernhardt, D. L.; and Dube, R. P.: "Data Base Technology Applied to Engineering Data." Published in 2nd International Conference on Foundations of Computer Aided Process Design, Snowmass, Colorado, June 1983.
7. Miller, Ralph E., Jr.: "Human Problem Solving and Its Relationship to Computer Aided Engineering Systems." Invited presentation to the Engineering Advancement Association of Japan at the Autumn Software Seminar '82, Shuzenji, Japan, October 1982.
8. Miller, Ralph E., Jr.; and Dube, R. Peter: "Project Management of Large System Development." Invited presentation to the Nippon Data Processing Association, Tokyo, Japan, October 1982.
9. Johnson, H. R.; and Bernhardt, D. L.: "Engineering Data Management Activities Within the IPAD Project." Published in the Quarterly Bulletin of the IEEE Computer Society Technical Committee on Database Engineering, June 1982.
10. Miller, Ralph E., Jr.; and Owens, Herschel, G.: "Technical Productivity - The Central Issue of Human Problem Solving." Presented at AIAA international Annual Meeting, Baltimore, Maryland, May 1982.
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13. Dube, R. Peter; Herron, Gary J.; Schweitzer, Jean E.; and Warkentine, Erich R.: "An Approach for Management of Geometry Data." NASA Conference Publication 2143, IPAD Symposium Proceedings, Denver, Colorado, September 1980.
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18. Diggins, Ralph M.: "Preliminary Design of a Future Integrated Design System." NASA Conference Publication 2143, IPAD Symposium Proceedings, Denver, Colorado, September 1980.
19. Southall, John W.: "Requirements for Company-Wide Management of Engineering Information." NASA Conference Publication 2143, IPAD Symposium Proceedings, Denver, Colorado, September 1980.
20. Meyer, Donald D.: "Future Integrated Design Process." NASA Conference Publication 2143, IPAD Symposium Proceedings, Denver, Colorado, September 1980.
21. Anderton, Gordon L.: "Integration of Design Information." NASA Conference Publication 2143, IPAD Symposium Proceedings, Denver, Colorado, September 1980.
22. Comfort, Dennis L.: "Requirements for an Engineering DBMS." Article in Computerworld, October 1979.
23. Dube, R. Peter: "Preliminary Specification of Spline Curves." Published in IEEE Transactions on Computers, Vo. C-28, NO. 4, April 1979.
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26. Meyer, D. D.; Anderton, G. L.; and Crowell, H. A.: "The Design Process." AIAA Publication 78-1483, presented at the AIAA Aircraft Systems and Technology Conference, Los Angeles, California, August 1978.
27. Burner, H. B.; Ives, F.; Lixvar, J.; and Shovlin, D.: "The Design, Evaluation, and Implementation of the IPAD Distributed Computing System." Presented at the American Society of Civil Engineering Technical Council on Computer Practices Specialty Conference on Electronic Computing and Civil Engineering, June 1978.
28. Comfort, Dennis L.; and Erickson, Wayne J.: "RIM - A Prototype for a Relational Information Management System." Presented at the NASA Conference on Engineering and Scientific Data Management, May 1978.
29. Wahlstrom, Stig O.; and Loendorf, David D.: "User Requirements for IPAD." SME Technical Paper MS77-762, The Computer and Automated Systems Association of SME, 1977.
30. Miller, Ralph E., Jr.; and Fulton, Robert E.: "IPAD - Objectives, Scope, Implementation, Status." Presented to Interactive Design System Conference, sponsored by the Computer-Aided Design Centre-Cambridge, Stratford-Upon-Avon, England, April 1977.
31. Miller, Ralph E., Jr.; and Fulton, Robert E.: "IPAD - Objectives, Scope, Implementation." Presented to the Society of Manufacturing Engineers, Dallas, Texas, November 1976.

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16. Abstract

Early work is being done to apply data base technology to support the management of engineering data in the design and manufacturing environments. The principal objective of the IPAD project was to develop a computer software system for use in the design of aerospace vehicles. Two prototype systems were created for this purpose. Relational Information Manager (RIM) has become a successful commercial product. IPAD Information Processor (IPIP), a much more sophisticated system, is still under development.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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